Disentangling complete and incomplete fusion for $^{9}Be+^{187}Re$ system at near barrier energies

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The breakup of projectile before fusion leads to some unusual fusion mechanisms like incomplete fusion (ICF) and sequential complete fusion (SCF). Experimentally, it is not possible to separate SCF events from direct complete fusion (DCF). However, the complete fusion and incomplete fusion can be measured separately. Theoretically it is very difficult to calculate the complete and incomplete fusion cross section separately using different models. Very recently A. Diaz-Torres [1, 2] has developed a computer code platypus based on classical dynamical model wherein the complete and incomplete fusion cross sections are calculated separately. But this model is found to work very well at energies above the barrier energy. Here we have attempted to extrapolate the results of the code platypus by using simple Wong's formula in conjunction with the energy dependent Woods-Saxon potential (EDWSP) [3] in the below barrier energy region.

In particular, we have studied the fusion reaction between ^{9}Be, a weakly bound projectile, and ^{187}Re at near barrier energies. The ^{9}Be is a weakly bound nucleus having one neutron separation energy nearly 1.67MeV and easily breaks up into n+^{8}Be two body channel. The ^{8}Be is found either in ground state or in excited state. The so formed ^{8}Be is then dissociated into two alphas through delayed (life time ~10^{-16}s) and prompt (life time ~10^{-22}s) breakup processes [4, 5].

In Fig. 1 the complete fusion, CF, and total fusion, TF (CF+ICF), cross sections are plotted as a function of incident beam energy for $^{9}Be+^{187}Re$ system and are compared with the corresponding experimental data taken from Ref. [6]. Experimental CF and TF cross sections are very well reproduced at energies larger than and equal to 1.07times V_B while for energies smaller than $1.07V_B$ the calculations significantly under estimate the observations. In fact, at above barrier energies the quantum mechanical tunneling effect is not significant hence fusion can be described very well by the classical model resulting in a very good agreement between data and predictions. However, at around barrier energies along with the quantum mechanical tunneling various channel coupling effects play very important role in the determination of fusion cross section. Since in the classical dynamical model which is implemented in the

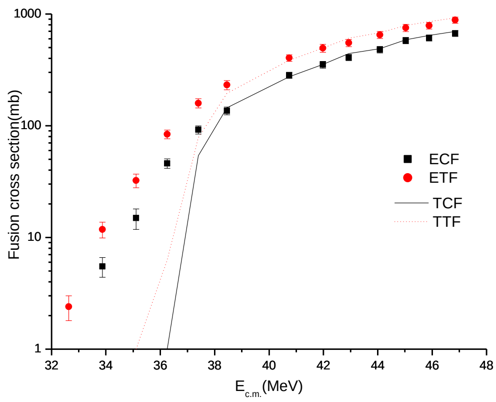

Fig. 1 *Fusion excitation functions for CF and TF processes for* ^{9}**Be+**^{187}**Re** *reaction are compared with the experimental data taken from Ref.(6)*

code, these effects responsible for sub barrier fusion enhancement are not taken into account and hence the experimental data are significantly underestimated in sub barrier energy region. In the energy region $E_{c.m.} \leq 1.07V_B$, EDWSP model is used to calculate the fusion cross section which consists in assuming that the contribution of ICF in TF is same as that predicted by code platypus for above barrier energies [See fig. 2] but in deep sub barrier energy region the TF data are still under estimated which clearly indicates that in this energy region, the contribution of ICF is larger than that predicted by platypus. It is shown more conspicuously in Fig.3. In nutshell, the complete fusion and incomplete fusion processes can be explained very well at above barrier energies by the classical dynamical model however it fails in the below barrier energy region where some alternative method is required for complete description.

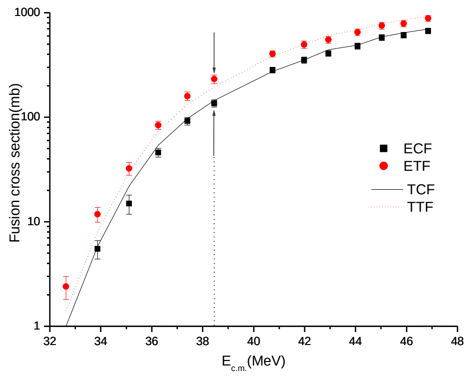

Fig.2 *The fusion cross section for* ^{9}***Be***+^{187}***Re*** *calculated by code platypus (for* $E/V_B \geq 1.07$*) and by EDWSP model (for* $E/V_B \leq 1.07$*) are compared with the experimental data taken from Ref. [6].*

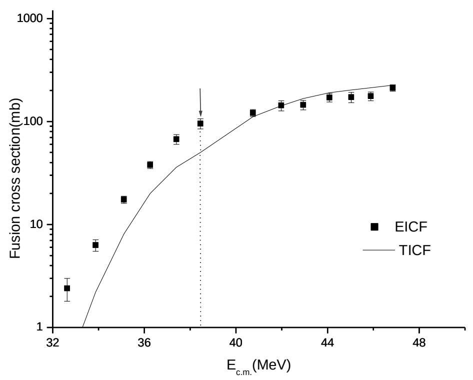

Fig.*3 Same as Fig. 2 but for ICF process.*

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